METHODOLOGY DEVELOPMENT FOR THE IMPROVEMENT OF MECHANICAL STRESS CONTROL IN MICRO AND NANO-TECHNOLOGIES

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INTRODUCTION

Continuous development of the Information Society is based on the constant improvement of micro-and nanotechnologies. Balance of international business and of employment is strongly linked to this evolution that involves more computational power, more data storage and more data communication. Europe is greatly concerned: some of our semiconductor manufacturers are now positioned among the first worldwide leaders partially due to EEC sponsoring. From a techno-economical point of view, the challenge seems to remain the same: shrinking transistor dimensions while increasing its performance. However today this objective involves integration of new materials such as Cu interconnects, high k materials, low k dielectrics, metal gates.

Alternative technologies based on other concepts (SOI, SiGe-C, SiC...) are also being investigated. A comparable situation exists in the area of optical devices (MOEMS) and microsystems (MEMS) where dimensions are decreasing and new materials will also be used in the near future. This evolution induces scientific and technological problems: high stresses can occur in these materials during process and operation, giving rise to damage and even to failure, as a result of differential thermal expansion or microstructure effect. Moreover, due to the high number of processing parameters, device reliability is becoming impossible to achieve by empirical means.

Mechanical stress control is becoming one of the major challenges for the future of micro and nanotechnologies. Worldwide industry leaders (IBM, INTEL, TEXAS INSTRUMENTS) and experts share this opinion (see “MRS BULLLETIN”, January 2002, dedicated to this topic) and confirm an essential aspect: current knowledge does not allow overcoming damage due to mechanisms that occur in micro-devices during process and operation. A national project, based on this conclusion, has recently been proposed and has obtained the agreement (http://www.rmnt.org) of the French government. The aim of this x-ray diffraction project concern metrology in MEMS and more precisely stress mapping at a micron scale on micro actuators and more complicated MEMS.

EXPERIMENTS AND FIRST RESULTS

Recent experiments have been done recently on Micro diffraction beam line 7.3.3.1. Polycrystalline silicon cantilever, 1.5 µm thick, covered with 0.56 µm gold thin film (MEMS from the CNES, France) have been analysed. Micro White and monochromatic X-ray

Diffraction measurements were done to measure stress and grain orientation maps on the micro system shown on figure 1. Calibration of the X-Y stage has been achieved using gold fluorescence (Fig. 2). Two populations of grains have been evidenced using poly (large <111> oriented grains) and monochromatic (small grains without preferential orientation) x-ray beam.

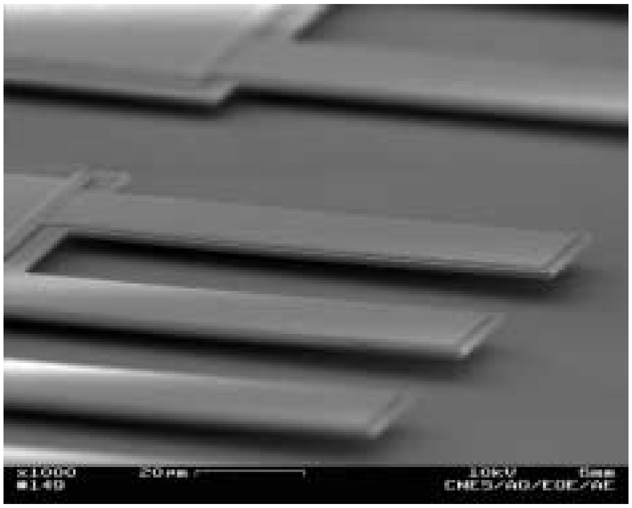

Figure 1. *MEB image of a cantilever array*

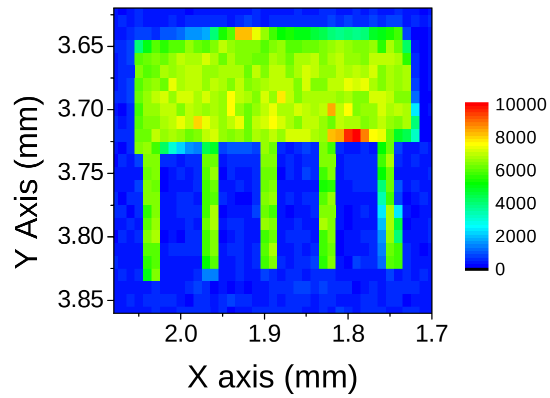

Figure 2. *Fluorescence map of the object shown on figure 1*

The total stress measured in flat region (Fig. 3) is equal to the macro stress obtained using other mechanical methods (cantilever deflection) such as confocal optical microscopy. The stress is tensile with magnitude of about 40 MPa. The x-ray stress profile decrease along the cantilever (Fig. 4) is similar to the curvature measure with the confocal microscopy (Fig. 5).

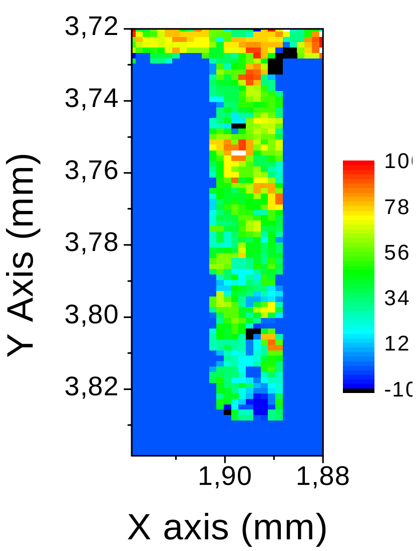

Figure 3. *Stress map on one cantilever*

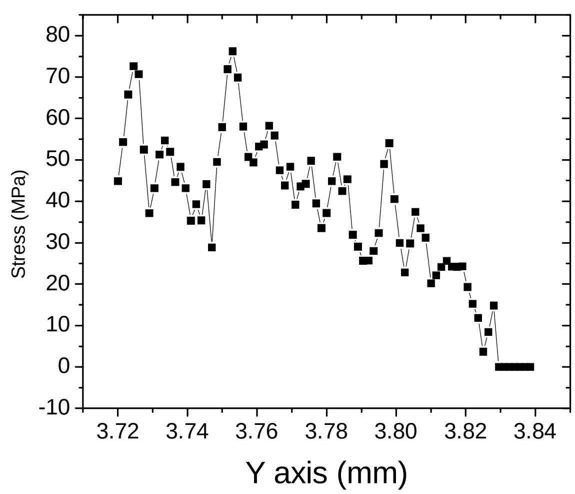

Figure 4. *Stress profile of σ_x along y axis*

In addition, X-ray diffraction measurements evidence strong grain to grain in plane strain and texture heterogeneities.

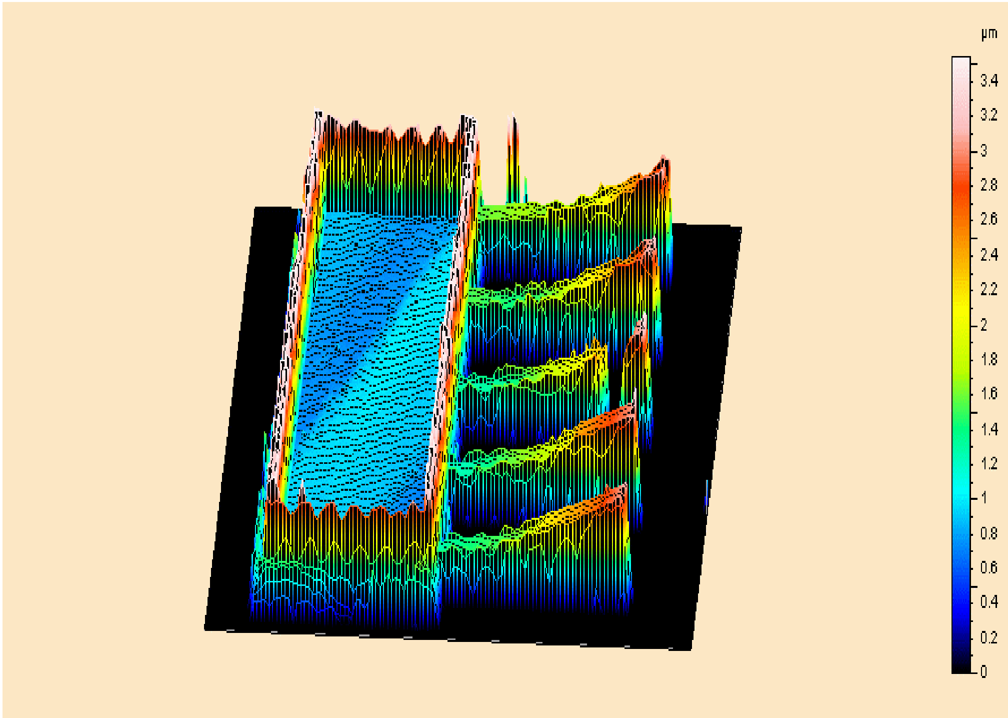

Figure 5. *3D optical image of the cantilever array shown on Fig. 1. The cantilever dimension are 100 micron length and 20 microns width.*

These first results have shown that micro scanning x-ray diffraction may give specific insight of in plane stress and grain orientation in selected phase structure of tenth micron scale object. It may be useful for validating other measurements done using mechanical methods and modeling.

This work was initiated with support of the Advanced Light Source at the Lawrence Berkeley National Laboratory.

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